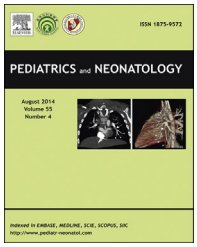
Pediatrics and Neonatology (2014) 55, 269–274

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: http://www.pediatr-neonatol.com



ORIGINAL ARTICLE

Sonographic Finding of Persistent Renal Pelvic Wall Thickening in Children

Nai-Chia Fan, You-Lin Tain*

Division of Pediatric Nephrology, Kaohsiung Chang Gung Memorial Hospital and Chang Gung University, College of Medicine, Kaohsiung, Taiwan

Received Jan 16, 2013; received in revised form Sep 18, 2013; accepted Oct 15, 2013
Available online 25 December 2013

Key Words
renal pelvic wall thickening;
ultrasound;
vesicoureteral reflux;
voiding cystourethrography

Objective: Renal pelvic wall thickening (RPWT) is a sonographic finding, which is associated with urinary tract infection (UTI) and other genitourinary tract abnormalities. We aimed to determine the prevalence of RPWT and whether persistent RPWT related to vesicoureteral reflux (VUR).
Materials and methods: We retrospectively reviewed sonographic findings of RPWT in children and adolescents referred for renal ultrasound study from January 2010 to December 2011. A total of 502 patients showing RPWT were included, 372 of whom received follow-up sonograms. Among them, 86 children underwent both follow-up sonograms and voiding cystourethrography studies. The association between persistent RPWT and VUR was analyzed.
Results: A total of 602 sonograms with RPWT were identified, accounting for a prevalence of 11.4%. Follow-up sonograms, revealing that these patients had recovered from RPWT, was found in 93.7% (459/490) of renal units and in 92.7% (345/372) of the patients. Children with persistent RPWT had a strong association with VUR occurrence ($p = 0.018$) and high VUR grading ($p = 0.006$) compared to those without persistent RPWT.
Conclusion: RPWT is a common finding in children and adolescents. Persistent RPWT is associated with VUR, especially with high grade VUR. Complementary uroradiological studies should be performed for children and adolescents with persistent RPWT.

* Corresponding author. Department of Pediatrics, Kaohsiung Chang Gung Memorial Hospital, 123 Dabi Road, Niausung, Kaohsiung 833, Taiwan.
E-mail addresses: tainyl@hotmail.com, tainyl@adm.cgmh.com.tw (Y.-L. Tain).

http://dx.doi.org/10.1016/j.pedneo.2013.10.007

1. Introduction

Renal sonography plays an important role in acute urinary tract infection (UTI) for the detection of genitourinary tract abnormalities, especially in young infants.[1,2] Renal pelvic wall thickening (RPWT) is a sonographic finding associated with UTI, urolithiasis, rejection after renal transplantation, vesicoureteral reflux (VUR), and obstruction.[3–9] We aimed to study the prevalence of RPWT in a pediatric population in a medical center and to determine the association between persistent RPWT and VUR.

2. Materials and Methods

We retrospectively analyzed sonographic findings of RPWT from January 2010 to December 2011 in our hospital. All children and adolescents aged <18 years, both hospitalized patients and outpatients, referred to our hospital for renal ultrasound study, were reviewed. During the study period, patients with renal ultrasound reports showing RPWT were included. The inclusion criteria were age <18 years and renal echo reports showing RPWT. Among these, patients who had both successively repeated renal ultrasound and voiding cystourethrography (VCUG) were finally analyzed for an association between persistent RPWT and VUR. Other uroradiological study results, including intravenous pyelogram and dimercaptosuccinic acid, were recorded as well.[10] Indications for repeated sonographic study included poor response to initial treatment and abnormalities identified by the first ultrasound study. These abnormalities included RPWT, dilated pelvis, dilated ureter, nephromegaly, focal renal mass, increased renal echogenicity, renal size discrepancy, ectopic kidney, and renal abscess.

All hospitalized patients underwent renal ultrasound on the 1st day or 2nd day after hospitalization. Renal ultrasound was performed with patients in the prone position, with the transducer in horizontal and transverse sections to the renal pelvis. RPWT was detected in both horizontal and transverse views. RPWT was defined as thickening measuring ≥1 mm as described previously.[4] This sonographic sign indicated a hypoechoic rim within the renal pelvic wall surrounded by increased mucosal hyperechogenicity (Figure 1). All ultrasound studies were performed with the same equipment (HP Image Point HX Ultrasound System, Philips Medical Systems, Andover, MA, USA), with an HP 21373 A curved ultrasound transducer under 3.5–7.5 MHz (HP Image Point HX Ultrasound System, Philips Medical Systems, Andover, MA, USA). All results were reviewed by one pediatric nephrologist (YL Tain) to avoid intra- and inter-operator variations. If thickening was persistent in the renal pelvic wall on successive ultrasound studies (the second renal sonography), this finding was defined as persistent RPWT. VCUG was not performed routinely after the first febrile UTI.[2] VCUG was indicated if the renal sonogram revealed a dilated pelvis, dilated ureter, and suspected duplex systems, which would suggest either high-grade VUR or obstructive uropathy, as well as in cases with recurrent UTI. VUR was detected by VCUG and classified following the international VUR grading system.[11]

Not all enrolled patients received repeated ultrasound studies. Only those with repeated ultrasound studies were classified into two groups: patients with and without persistent RPWT. These two groups were further subgrouped depending on the presence of VUR. Underlying diseases of these patients were recorded through chart review approved by the institutional review board (IRB) at Chang Gung Memorial Hospital, Kaohsiung, Taiwan. Data were presented as mean ± standard deviation (SD). Chi-square analysis or Fisher's exact test, *t* test, and binary logistic regression were used to compare nominal data between the two groups by means of commercially available software (SPSS 14.0; SPSS Inc., Chicago, IL, USA). A p value <0.05 was considered statistically significant.

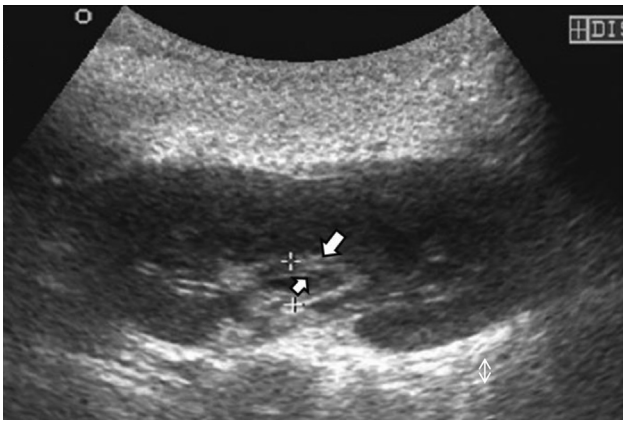


Figure 1 Prone longitudinal scan of the kidney showing renal pelvic wall thickening. The two white crosses indicate renal pelvis and the two white arrows indicate hypoechoic rim surrounded by increased mucosal hyperechogenicity.

3. Results

A total of 5299 renal ultrasound studies from January 2010 to December 2011 were reviewed. Among them, 602 sonograms with RPWT were identified accounting for a prevalence of 11.4%. In the 602 renal ultrasound studies, there were 502 patients, including 255 males and 247 females. The mean age was 26.5 ± 43 months (aged between 0.1 months and 209 months). Initial presentations of these 502 patients included febrile episodes (n = 451, 89.8%), pyuria (n = 372, 74.1%), and gross hematuria (n = 3, 0.6%). Febrile UTI was diagnosed in 235 cases (46.8%) and non-febrile UTI was diagnosed in four cases (0.8%). The common pathogens of UTI (n = 239) included *Escherichia coli* (n = 159, 66.5%), *E. coli* extended-spectrum β-lactamases strain (n = 64, 26.8%), *Proteus mirabilis* (n = 4, 1.7%), *Klebsiella pneumoniae* (n = 4, 1.7%), *Pseudomonas aeruginosa* (n = 2, 0.8%), and others (n = 6, 2.5%).

Of 502 patients, 372 patients (74.1%) had repeated renal sonograms. The follow-up renal sonographies were arranged for the abnormalities in the first echo reports. These 372 patients had a total of 490 renal units with RPWT at their initial renal ultrasound studies. A renal unit presented each kidney separately. There was an average of 16.8 ± 18.9 days between the repeated performances of renal ultrasound in all enrolled patients. More than 75% of patients received repeated renal ultrasound study in

Table 1 Demographic and clinical characteristics of patients with follow-up renal ultrasound.

	Total (n = 372)	With persistent RPWT (n = 27)	Without persistent RPWT (n = 345)	p value*
Sex, n (%)				0.11
M	181 (48.7)	9 (33.3)	172 (49.9)	
F	191 (51.3)	18 (66.7)	173 (50.1)	
Age at enrollment (months), n (%)				<0.001*
≤12	253 (68.0)	6 (22.2)	247 (71.6)	
>12	119 (32.0)	21 (77.8)	98 (28.4)	
Mean age in months ± SD (range)	24.2 ± 39.7 (0.1–205)	63.3 ± 58.6 (3.0–205)	22.5 ± 37.8 (0.1–192)	
UTI, n (%)	190 (51.1)	9 (31.3)	181 (52.5)	0.07
Recurrent UTI, n (%)	24 (6.5)	7 (25.0)	17 (2.2)	0.001*
Having VCUG, n (%)	86 (23.1)	14 (51.9)	72 (20.9)	

p values calculated using chi-square test for categorical data, and t test for continuous data (e.g. mean age in months).
*$p < 0.05$, statistic significance.
RPWT = renal pelvic wall thickening; UTI = urinary tract infection; VCUG = voiding cystourethrography.

20 days. Disappearance of the PWT occurred in 93.7% (459/490) of renal units and in 92.7% (345/372) of the patients who had repeated renal sonograms.

Among 372 patients with repeated renal sonograms, 27 children had persistent RPWT and 345 children did not have persistent RPWT. Children with persistent RPWT were older at enrollment ($p < 0.001$) and had a higher recurrent UTI rate ($p = 0.001$) than children without persistent RPWT (Table 1). There was no difference in sex or UTI occurrence between the two groups. Among 27 children with persistent RPWT, 14 had received VCUG study. Eleven out of these 14 cases showed VUR.

The other 16 children who did not receive VCUG study ($n = 13$) or had absence of VUR ($n = 3$), included 10 patients with repeated renal ultrasound performed within 7 days (median 4 days, range 1–11 days), three patients with neurogenic bladder, two patients without significant underlying disease, and one patient who had received VCUG study prior to this study.

Among 345 patients without persistent RPWT, 72 (20.9%) underwent VCUG study. Twenty-six of 72 patients had VUR. The characteristics of patients with VUR, either with or without persistent RPWT, are shown in Table 2. The detection rates of VUR in patients with and without persistent RPWT were 79% (11/14) and 36% (26/72), respectively. The persistent RPWT group showed a higher VUR occurrence ($p = 0.006$) and higher VUR grading (VUR grading III ~ V; $p = 0.004$) compared to those in the group without persistent RPWT (Table 2). We further studied the relationship between VUR and abnormal renal sonographic findings, including persistent RPWT, small or hypoplastic kidney, hydronephrosis, pelviectasis, ureter dilatation, globular shaped kidney, nephromegaly, and urinary bladder wall thickening in patients with repeated renal ultrasound and VCUG. As shown in

Table 2 Demographic and clinical characteristics of patients with follow-up renal ultrasound and voiding cystourethrography.

	Total (n = 86)	With persistent RPWT (n = 14)	Without persistent RPWT (n = 72)	p value*
With VUR, n (%)	37 (43.0)	11 (78.6)	26 (36.1)	0.006*
VUR grading				
I	8 (9.3)	2 (14.3)	6 (8.3)	
II	8 (9.3)	1 (7.1)	7 (9.7)	
III	11 (12.8)	2 (14.3)	9 (12.5)	
IV	4 (4.7)	2 (14.3)	2 (2.8)	0.004†,*
V	6 (7.0)	4 (28.6)	2 (2.8)	
Characteristics				
Recurrent UTI	12 (14.0)	5 (35.7)	7 (9.7)	
CAKUT	5 (5.8)	3 (21.4)	2 (2.8)	
Status post deflux	3 (3.5)	1 (7.1)	2 (2.8)	
No underlying diseases	17 (19.7)	2 (14.3)	15 (20.9)	
DMSA, n (%)	14 (16.3)	5 (35.7)	9 (12.5)	
With cold area, n (%)	7 (8.1)	4 (28.6)	3 (4.2)	

*$p < 0.05$, statistic significance.
RPWT = renal pelvic wall thickening; VUR = vesicoureteral reflux; UTI = urinary tract infection; CAKUT = congenital anomalies of the kidney and urinary tract; DMSA = dimercaptosuccinic acid renal scan.
† Present p value of these two groups in high grade VUR (VUR grading III ~ V).

Table 3 Factors associated with VUR (total renal units, $n = 169$ RUs).

Characteristics	Non-VUR ($n = 121$)	VUR ($n = 48$)	Unadjusted OR for being VUR (95%CI)	p value	Adjusted OR for being VUR (95% CI)	p value
Renal US presentation, n (%)				0.3		0.7
Abnormal	83 (68.6)	37 (77.1)	1.5 (0.7 to 3.3)		0.8 (0.3 to 2.5)	
Normal	38 (31.4)	11 (22.9)	1 (Reference)		1 (Reference)	
Small or hypoplastic kidney, n (%)				0.02*		0.006*
Yes	2 (1.7)	5 (10.4)	**6.9 (1.3 to 37.0)**		**13.8 (2.1 to 90.2)**	
No	119 (98.3)	43 (89.6)	1 (Reference)		1 (Reference)	
Hydronephrosis, n (%)				0.1		0.08
Yes	5 (4.1)	5 (10.4)	2.7 (0.7 to 9.8)		4.4 (0.8 to 23.9)	
No	116 (95.9)	43 (89.6)	1 (Reference)		1 (Reference)	
Pelviectasis, n (%)				0.9		0.4
Yes	54 (44.6)	21 (43.8)	1.0 (0.5 to 1.9)		1.6 (0.5 to 5.2)	
No	67 (55.4)	27 (46.2)	1 (Reference)		1 (Reference)	
Ureter dilatation, n (%)				0.9		0.4
Yes	47 (38.8)	19 (39.6)	1.0 (0.5 to 2.0)		0.6 (0.2 to 1.8)	
No	74 (61.2)	29 (60.4)	1 (Reference)		1 (Reference)	
Globular shaped kidney, n (%)				0.7		0.6
Yes	20 (16.5)	9 (18.8)	1.2 (0.5 to 2.8)		1.3 (0.5 to 3.7)	
No	101 (83.5)	39 (81.2)	1 (Reference)		1 (Reference)	
Nephromegaly, n (%)				0.7		0.7
Yes	10 (8.3)	5 (10.4)	1.3 (0.4 to 4.0)		1.3 (0.4 to 4.6)	
No	111 (91.7)	43 (89.6)	1 (Reference)		1 (Reference)	
Urinary bladder wall thickening, n (%)				0.2		0.2
Yes	3 (2.5)	3 (6.3)	2.6 (0.5 to 13.5)		3.2 (0.6 to 18.0)	
No	118 (97.5)	45 (93.7)	1 (Reference)		1 (Reference)	
Persistent RPWT, n (%)				0.008*		0.018*
Yes	6 (5.0)	9 (74.4)	**4.4 (1.5 to 13.2)**		**4.5 (1.3 to 15.9)**	
No	115 (95.0)	39 (25.6)	1 (Reference)		1 (Reference)	
Age (months), n (%)				0.4		0.5
$\leq$12	70 (57.9)	21 (43.8)	0.7 (0.3 to 1.6)		0.8 (0.4 to 1.7)	
$>$12	51 (42.1)	27 (56.2)	1 (Reference)		1 (Reference)	
Sex, n (%)				0.6		0.3
Male	32 (26.4)	11 (22.9)	0.8 (0.4 to 1.8)		0.6 (0.2 to 1.7)	
Female	89 (73.6)	37 (77.1)	1 (Reference)		1 (Reference)	
UTI recurrence, n (%)				0.2		0.7
Yes	11 (9.1)	8 (16.7)	2.0 (0.8 to 5.3)		1.3 (0.4 to 4.2)	
No	110 (90.9)	40 (83.3)	1 (Reference)		1 (Reference)	

Significant results are highlighted in bold.
OR = odds ratio, each OR of the variable was adjusted by the other factors in the logistic regression model.
*$p < 0.05$ indicates a statistically significant difference.
RU = renal unit; VUR = vesicoureteral reflux; US = ultrasound; RPWT = renal pelvic wall thickening; UTI = urinary tract infection.

Table 3, small/hypoplastic kidney and persistent RPWT had significant associations with VUR. Moreover, persistent RPWT was the only sonographic finding to be associated with high grade VUR [Table 4; adjusted odds ratio (OR) = 8.9, 95% confidence interval (CI) = 2.3–34.9, $p = 0.002$].

4. Discussion

Our major findings are as follows: (1) RPWT is a common sonographic finding in the pediatric population; and (2) persistent RPWT has a significant association with high grade VUR compared to the other abnormal renal ultrasound findings. Previously, ultrasonic studies have focused on associated diseases of RPWT whereas we were more concerned with elucidating the right time to detect RPWT occurrence and the role of persistent RPWT. Previous reports showed that RPWT signs were related to UTI, urolithiasis, rejection after renal transplantation, VUR, and obstruction.[3–9] In this study, we found that persistent RPWT signs in consecutive renal ultrasound had a strong association with VUR, particularly high-grade VUR.

Table 4 Factors associated with high grade VUR (total renal units, $n = 169$ RUs).

Characteristics	Non-high grade VUR ($n = 141$)	High grade VUR ($n = 28$)	Unadjusted OR for being high grade VUR (95% CI)	p value	Adjusted OR for being high grade VUR (95% CI)	p value
Renal US presentation, n (%)				0.2		0.5
Abnormal	97 (68.8)	23 (82.1)	2.0 (0.7 to 5.8)		1.5 (0.4 to 5.9)	
Normal	44 (31.2)	5 (17.9)	1 (Reference)		1 (Reference)	
Small or hypoplastic kidney, n (%)				0.4		0.3
Yes	5 (3.5)	2 (7.1)	2.1 (0.4 to11.4)		2.9 (0.4 to 20.1)	
No	136 (96.5)	26 (92.9)	1 (Reference)		1 (Reference)	
Hydronephrosis, n (%)				0.3		0.7
Yes	7 (5.0)	3 (10.7)	2.3 (0.6 to 9.5)		1.4 (0.2 to 10.1)	
No	134 (95.0)	25 (89.3)	1 (Reference)		1 (Reference)	
Pelviectasis, n (%)				0.9		0.6
Yes	63 (44.7)	12 (42.9)	0.9 (0.4 to 2.1)		0.7 (0.2 to 2.9)	
No	78 (55.3)	16 (57.1)	1 (Reference)		1 (Reference)	
Ureter dilatation, n (%)				0.7		0.9
Yes	54 (38.3)	12 (82.8)	1.2 (0.5 to 2.7)		0.9 (0.2 to 3.5)	
No	87 (61.7)	16 (8.6)	1 (Reference)		1 (Reference)	
Globular shaped kidney, n (%)				0.5		0.8
Yes	23 (16.3)	6 (42.9)	1.4 (0.5 to3.8)		1.1 (0.3 to 3.4)	
No	118 (83.7)	22 (57.1)	1 (Reference)		1 (Reference)	
Nephromegaly, n (%)				0.7		0.8
Yes	12 (8.5)	3 (10.7)	1.3 (0.3 to 4.9)		1.2 (0.3 to 5.5)	
No	129 (91.5)	25 (89.3)	1 (Reference)		1 (Reference)	
Urinary bladder wall thickening, n (%)				1.0		0.9
Yes	5 (3.5)	1 (3.6)	1.0 (0.1 to 9.0)		1.2 (0.1 to 11.8)	
No	136 (96.5)	27 (96.4)	1 (Reference)		1 (Reference)	
Persistent RPWT, n (%)				<0.001*		0.002*
Yes	7 (5.0)	8 (82.8)	**7.7(2.5 to 23.4)**		**8.9 (2.3 to 34.9)**	
No	134 (95.0)	20 (8.6)	1 (Reference)		1 (Reference)	
Age (months), n (%)				0.1		0.8
≤ 12	78 (55.3)	13 (46.4)	0.6 (0.3 to 1.1)		0.9 (0.3 to 2.4)	
>12	63 (44.7)	15 (53.6)	1 (Reference)		1 (Reference)	
Sex, n (%)				0.7		1.0
Male	35 (24.8)	8 (28.6)	1.2 (0.5 to 3.0)		1.0 (0.3 to 2.8)	
Female	106 (75.2)	20 (71.4)	1 (Reference)		1 (Reference)	
UTI recurrence, n (%)				0.6		0.4
Yes	15 (10.6)	4 (14.3)	1.4 (0.4 to 4.6)		0.5 (0.1 to 2.5)	
No	126 (89.4)	24 (85.7)	1 (Reference)		1 (Reference)	

Significant results are highlighted in bold.
OR = odds ratio, each OR of the variable was adjusted by the other factors in the logistic regression model.
*$p < 0.05$ indicates a statistically significant difference.
RU = renal unit; VUR = vesicoureteral reflux; US = ultrasound; RPWT = renal pelvic wall thickening; UTI = urinary tract infection.

It is noteworthy that most cases with RPWT were detected during the acute phase of infection. In our hospitalized children, the first renal ultrasound was performed within 3.8 ± 3.4 days from the onset of fever. The follow-up renal ultrasound was performed 16.8 ± 18.9 days after the first renal ultrasound. More than 90% of patients who received follow-up renal ultrasound recovered from RPWT. For UTI and non-UTI children in this study, the recovery rate of RPWT was 95.3% in UTI patients and 90.1% in non-UTI patients. Since the recovery rate of RPWT in UTI and non-UTI children was similar, it seemed that an acute UTI episode was not the leading cause for the occurrence of persistent RPWT. In addition, our patients did not present urolithiasis or rejection after renal transplantation. The trend for a high recovery rate of RPWT may come from quickly resolved acute infections, acute inflammation or obstruction in the majority of patients. Thus, RPWT was considered to be an acute phase sign. If RPWT lasted longer than the usual duration (2 weeks) after the first renal ultrasound, it suggested that VUR or genitourinary tract obstruction should be evaluated. Given that most patients recovered from RPWT after their clinical symptoms began

to improve, it is necessary to perform renal ultrasound as early as possible to better understand the timing of RPWT occurrence. The RPWT occurrence pattern in this study showed a large variation, due to some patients receiving follow-up renal ultrasound at different intervals. Thus, a short interval follow-up may provide more information about the recovery duration of RPWT.

In this study, we further compared persistent RPWT with other abnormal findings on renal ultrasound which were studied and proved to have a positive correlation to VUR previously.[7,12] Next, confounders including children's age, sex, and UTI recurrence[9] were put together with the above factors into logistic regression, to detect their influence on each other and the association with VUR. Small kidney or hypoplastic kidney was associated with VUR (adjusted OR = 13.8, CI = 2.1—90.2, $p = 0.006$). The adjusted OR of children with persistent RPWT with VUR is 4.5 times as large as those of children without persistent RPWT. Moreover, the adjusted OR of children with persistent RPWT with high grade VUR is 8.9 times as large as those of children without persistent RPWT (CI = 2.3—34.9, $p = 0.002$). Our results indicated that only persistent RPWT was significantly associated with high grade VUR compared to the other factors.

The sensitivity of renal ultrasound to first febrile UTI in detecting VUR and renal parenchymal defects remains questionable.[13—16] Although RPWT is one of the abnormal findings in renal sonograms indicating the possibility of VUR,[8,13] persistent RPWT has a strong association with VUR, especially with high grade VUR. In this study, we observed that three children in the persistent RPWT group had VUR. All received deflux procedures later. Their RPWT recovered following correction of their VUR. RPWT has been proposed to be due to subepithelial edema, acute inflammatory infiltration, fibrosis, or smooth muscle hypertrophy, followed by chronic inflammation.[5,17,18] Our data suggest that VUR may cause RPWT by increasing renal pelvic pressure, similar to the mechanism of genitourinary obstruction.

Our study has some limitations. First, ultrasound study is an operator-dependent technique. Although each renal sonogram was reviewed by one pediatric nephrologist, and RPWT is a common parameter in our hospital, we did not measure inter- and intra-operator variations in this study. Another limitation is the small sample size in the subgroups. As mentioned above, VCUG is not a routine procedure to perform after each UTI episode. There may be some missing data in those patients without VCUG study.

In conclusion, RPWT is a common abnormal finding of renal sonograms in the pediatric population. Persistent RPWT is the only factor that correlates with VUR, especially with high-grade VUR. Most UTI-related RPWT recovered after about 2 weeks follow-up. Complementary uroradiological studies could be considered if this sign is persistent.

Conflict of interest

None declared.

References

1. Mori R, Lakhanpaul M, Verrier-Jones K. Diagnosis and management of urinary tract infection in children: summary of NICE guidance. *BMJ* 2007;**335**:395—7.
2. Subcommittee on Urinary Tract Infection. Steering Committee on Quality Improvement and Management, Roberts KB. Urinary tract infection: clinical practice guideline for the diagnosis and management of the initial UTI in febrile infants and children 2 to 24 months. *Pediatrics* 2011;**128**:595—610.
3. Avni EF, Van Gansbeke D, Thoua Y, Matos C, Marconi V, Lemaitre L, et al. US demonstration of pyelitis and ureteritis in children. *Pediatr Radiol* 1988;**18**:134—9.
4. Tain YL. Renal pelvic wall thickening in childhood urinary tract infections—evidence of acute pyelitis or vesicoureteral reflux? *Scand J Urol Nephrol* 2003;**37**:28—30.
5. Nicolet V, Carignan L, Dubuc G, Hébert G, Bourdon F, Paquin F. Thickening of the renal collecting system: a nonspecific finding at US. *Radiology* 1988;**168**:411—3.
6. Peters C, Rushton HG. Vesicoureteral reflux associated renal damage: congenital reflux nephropathy and acquired renal scarring. *J Urol* 2010;**184**:265—73.
7. Pennesi M, L'erario I, Travan L, Ventura A. Managing children under 36 months of age with febrile urinary tract infection: a new approach. *Pediatr Nephrol* 2012;**27**:611—5.
8. Sorantin E, Fotter R, Aigner R, Ring E, Riccabona M. The sonographically thickened wall of the upper urinary tract system: correlation with other imaging methods. *Pediatr Radiol* 1997;**27**:667—71.
9. Mitterberger M, Pinggera GM, Feuchtner G, Neururer R, Bartsch G, Gradl J, et al. Sonographic measurement of renal pelvis wall thickness as diagnostic criterion for acute pyelonephritis in adults. *Ultraschall Med* 2007;**28**:593—7.
10. Paterson A. Urinary tract infection: an update on imaging strategies. *Eur Radiol* 2004;**14**:L89—100.
11. Lebowitz RL, Olbing H, Parkkulainen KV, Smellie JM, Tamminen-Möbius TE. International system of radiographic grading of vesicoureteric reflux. International Reflux Study in Children. *Pediatr Radiol* 1985;**15**:105—9.
12. Lee JH, Kim MK, Park SE. Is a routine voiding cystourethrogram necessary in children after the first febrile urinary tract infection? *Acta Paediatr* 2012;**101**:e105—9.
13. Alton DJ, LeQuesne GW, Gent R, Siegmann JW, Byard R. Sonographically demonstrated thickening of the renal pelvis in children. *Pediatr Radiol* 1992;**22**:426—9.
14. Jahnukainen T, Honkinen O, Ruuskanen O, Mertsola J. Ultrasonography after the first febrile urinary tract infection in children. *Eur J Pediatr* 2006;**165**:556—9.
15. Mahant S, Friedman J, MacArthur C. Renal ultrasound findings and vesicoureteral reflux in children hospitalised with urinary tract infection. *Arch Dis Child* 2002;**86**:419—20.
16. Smellie JM, Rigden SP, Prescod NP. Urinary tract infection: a comparison of four methods of investigation. *Arch Dis Child* 1995;**72**:247—50.
17. Han SW, Maizels M, Chou PM, Fernback SK, Cheng EY, Furness PD 3rd. Lamina muscularis propria thickness of renal pelvis predicts radiological outcome of surgical correction of ureteropelvic junction obstruction. *J Urol* 2001;**165**:1648—51.
18. Tsai JD, Huang FY, Lin CC, Tsai TC, Lee HC, Sheu JC, et al. Intermittent hydronephrosis secondary to ureteropelvic junction obstruction: clinical and imaging features. *Pediatrics* 2006;**117**:139—46.